Mars Exploration Rover (MER) Battery Control Board

Topic: **Battery Management and Packaging**

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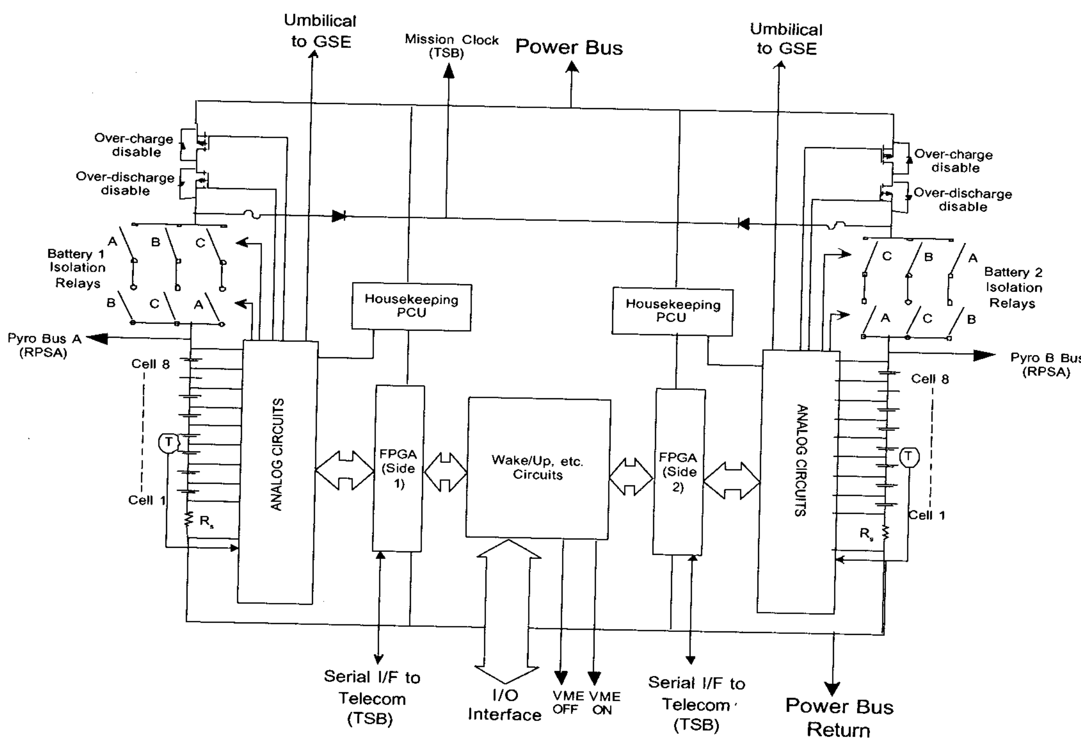
Abstract

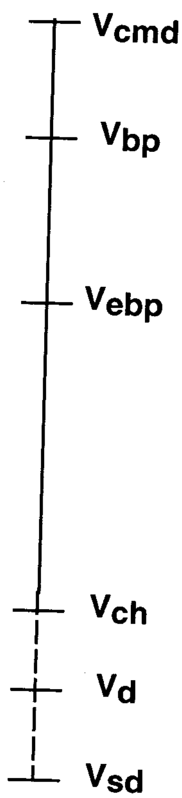
The Mars Exploration Rover Mission is the NASA mission to Mars during the 2003 launch opportunity. Two identical spacecraft MER A and MER B will launch in June and July of 2003 and arrive at Mars in January and February of 2004. These two spacecraft will deliver to the Martian surface two mobile platforms (Rovers) to perform remote sensing and in-situ experiments.

During several phases of the mission, and particularly when the Rovers are on the Martian surface, energy storage will be provided by two secondary batteries. Each Rover will contain two batteries each consisting of eight (8) series-connected Li-Ion cells. The main function of the Rover Battery Control Board (RBCB) is the optimal management of the Rover Batteries. The RBCB will also perform other functions such as the wake-up logic for the VME computer running flight software, relay and heater control, telemetry including data collection and storage, and serial bus control. The RBCB consists of two identical sections each of which control one battery. The functionality of the RBCB resides within an FPGA. Nearly all communication with the RBCB is done through serial buses (see block diagram below). A high efficiency buck converter powers the RBCB. This converter is powered by the main power bus, if the bus is down, the RBCB will be down, and will POR when the bus comes back up. There is an under voltage lockout on the buck converter set for approximately 15V. If the FPGA is down or has failed, the correct default is to have the battery online. To prevent over discharge, however, an analog comparator will be used to take the battery offline at a low voltage.



Rover Battery Control Board Block Diagram

During normal spacecraft operation energy available from the Solar Array is used to power loads, charge the battery, or dissipated through the shunt radiators. When the battery is connected to the spacecraft bus, the battery voltage is the same as the bus voltage. The fraction of energy that is used to charge the battery depends on the difference between the bus/battery voltage and the shunt voltage. During charge, the battery will be at a lower voltage relative to the shunt voltage, as the battery gets charged the voltage of the battery will go up with a concurrent decrease in the charge current. It is the difference between the shunt voltage and the increase in the battery voltage that modulates the battery charge current. As the battery approaches full state of charge, the charge current will have dropped and it is at this point that the RBCB cell by-pass circuitry goes into effect (See Sketch). The RBCB voltage settings for battery charge control are presently defined as follows:



1. V_{cmd} (V command) = V_{sc} (V stop charge) one of four programmable cell voltage levels (3.8, 4.0, 4.1, 4.2) which take the battery 'off-charge' when they are reached by any cell.
2. V_{bp} (V bypass) = V_{cmd} – 50 mV. If a cell is 50 mV from the stop charge condition, and other cells are still charging, that cell will be by-passed.
3. V_{ebp} (Vend bypass) = V_{cmd} – 150 mV. Once a cell is in by-pass it will remain in by-pass until it falls below this voltage limit.
4. V_{ch} (V charge) = V_{cmd} – 250 mV. When all cells meet this condition, the charge FET is closed allowing battery to charge again. This is also the default condition after POR.
5. V_d (V discharge) = 3.4 V This closes the discharge FET; all cells must be above this voltage before the battery can be discharged.
6. V_{sd} (V stop discharge) = 3.2 V If any cell reaches this limit the discharge FET is opened, disabling further discharge.

The by-pass cell circuitry will allow diverging cells to catch up and have all cells reach the specified voltage limit at the same time. The by-pass control is envisioned to work as follows: When the battery is nearly fully charged, if there is an out-lier cell that reaches the V_{bp} voltage first, this cell is partially bypassed through a 33Ω resistor (4.0 V / 33Ω = 0.121 A). Cells in the by-pass mode will get approximately 121 mA less charging current than the other cells. When a cell is bypassed, the rate of voltage rise will slow down due to the lesser current, allowing other cells to catch-up. As subsequent cells reach the V_{bp}, they are also by-passed and their rate of voltage rise also decreases. When the battery is nearly fully charged and all eight cells are within 50 mV of V_{cmd} (i.e. in the by-pass mode between V_{cmd} and V_{bp}) charging stops. Also, if for any reason a cell reaches V_{cmd} charging stops. The cell balancing or cell by-pass circuitry allows for optimum battery charge by minimizing cell divergence.

RBCB testing will be performed during the coming months at the breadboard and engineering model levels to validate performance and functionality. Results of the testing and the final design specifications will be presented at the meeting.